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Structural Characteristics Of High Volume Flyash Concrete Subjected To Elevated Temperature

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Abstract
Fly ash is a constituent included in concrete batches to enhance their durability and compressive strength. The increased temperatures induced a chemical reaction in the gel, resulting in a reduction in the strength of fly soil concrete. The deterioration of the matrix bonding was the cause of the decrease in strength. There are many techniques by which fly ash may be incorporated into concrete. This material has the ability to substitute a portion or the whole of the fine particles, a portion or the entirety of the cement, or even function as an additional component that improves the formation of certain characteristics in the concrete. Numerous international enterprises heavily depend on pozzolanic concrete, especially those operating in the nuclear, oil and gas, and electrical sectors. Pozzolanic concrete is also used in the construction of bridges and tunnels. Considering their extended exposure to the external environment, these concrete slabs not only experience elevated internal temperatures but also carry an inherent risk of fire. Although concrete is not prone to immediate combustion, it may nonetheless suffer substantial damage or even collapse when subjected to very high temperatures. This work investigated the modulus elasticity, split tensile strength, and compressive strength of fly ash concrete at temperatures up to 120 degrees Celsius. The study used a water-to-cement ratio of 0.5 weight per unit mass and a mixture ratio of 1:1.45:2.2:1.103. Throughout this investigation, fly ash was used as a substitute for cement in many methodologies. Furthermore, measurements were taken for the elastic modulus, compressive strength, and split tensile strength of the substrate. The proportion of cement used determined the replacement ratios, which varied between 30% and 50%. The compressive strength, split tensile strength, and elastic modulus of several types of fly-ash concrete were determined at varying temperatures and after varying curing durations ranging from 28 to 56 days. The results indicated that the compressive strength, split tensile strength, and elastic modulus of the concrete were similar to those of the standard concrete without fly ash, up to a cement replacement level of 30%. The control mixture exhibited superior performance in split tensile strength, elastic modulus, and compressive strength compared to concrete mixes using 30%, 40%, or 50% fly ash as a substitute for cement. Regardless of the historical point at which the pairings were established, this statement remained valid. Conversely, the effectiveness of a combination will increase with time. Concrete mixes with 30%, 40%, or 50% fly ash instead of cement exhibit compressive strength reductions of 11.4%, 30.1%, 28.9%, and 27.5%, respectively, at a temperature of 120 degrees Celsius, in comparison to compositions without fly ash.

Keywords: Component; Construction Materials, Fly ash, Pozzolanic concrete)

I INTRODUCTION

The nuclear and power-generating sectors, together with the oil and gas industries, are The nuclear and power-generating industries, together with the oil and gas industries, are among the primary users of pozzolanic concretes, which are used in a wide variety of applications throughout the whole world. In the oil and gas sectors, pozzolanic concretes are also used in various capacities. These concretes are finding more and more applications on a daily basis as a result of their improved structural performance, their friendliness to the environment, and the implications they have for the conservation of energy. This is due to the fact that they care about the environment. In spite of the fact that it is generally accepted that concrete is a good material for fireproofing, it is important to note that high temperatures have the ability to inflict severe damage or even lead to the full collapse of the building. In spite of the fact that it is well understood that concrete is a great material for fireproofing, this is the situation that continues to exist. Both the longevity of concrete and the pace at which it acquires strength over time might be improved by the addition of these compounds, which have the potential to strengthen concrete. Additionally, they have the potential to slow down the pace at which heat is generated, which is beneficial for mass concrete. This is a feature that they possess. At temperatures ranging from 100 to 300 degrees Celsius, concrete is known to experience changes in its properties, the most notable of which is the metamorphosis that occurs between these two temperatures. At temperatures more than 300 degrees Celsius, the mechanical qualities of an item begin to degrade. This is because of the increased temperature. The manner in which concrete reacts when it is exposed to high temperatures is governed by a variety of elements, some of which include the heating rate, the peak temperatures, the dehydration of the CSH gel, the phase transitions, and the thermal incompatibility between the aggregates and the cement paste throughout the heating process. When concrete is heated to a high degree, each of these variables comes into action and comes into play simultaneously. On the other hand, conducting non-destructive concrete quality checks on structures that have been subjected to temperatures below freezing or fire may prove to be a difficult task. These kinds of constructions could have lost some of the integrity that they had when they were first built. For the most part, the majority of the organisations that are now in existence have a tendency to use the age of 28 as a benchmark for eligibility for membership.

1. II EXPERIMENTAL STUDY

When concrete was exposed to temperatures as high as 120 degrees Celsius and when a large amount of fly ash was replaced for cement in the concrete, the primary purpose of the experiment was to see how the concrete behaved under these conditions. During the course of this inquiry, the compressive strength, split tensile strength, and modulus of elasticity of the material were the primary characteristics that were investigated. The components that were used in the production of the concrete samples, in addition to the outcomes of the tests that were carried out on the samples, are as follows.

1.1 Cement

Using cement from Ordinary Portland Cement (OPC) Grade 43, which is a high-quality Portland cement, all of the concrete combinations, including the cubes and cylinders that were utilised in the casting process, were created. Throughout the whole of the batch of cement, there was a consistent shade of grey that had a little greenish tint, and there were no firm lumps discovered in the mixture. In order to ensure that it complies with Indian safety rules and requirements (BIS-8112:1989), it was put through its paces. According to what was said before, the conclusions of the tests are summarised in Table 2.1, which contains the results of the experiment.

Table 2.1: Physical Properties of cement

Characteristics	Values obtained
Normal consistency	32%
Initial setting time (minutes)	58 min.
Final setting time (minutes)	260 min
Fineness (%)	3.5 %
Specific gravity	3.09

1.2 Coarse aggregates

The activity that was now taking place made use of coarse aggregates that had a maximum size that ranged from ten to twenty millimetres. These aggregates could be discovered in the area around the activity and its surroundings. There were two times that the aggregates that were 10 millimetres in size were sieved. The first time, they were put through a sieve that had a diameter of 10 millimetres, and then they were put through a sieve that had a diameter of 4.75 millimetres. In the subsequent step, the aggregates that were 0 millimetres in size were passed through a sieve that had a size of. The next step was to wash them in order to get rid of any dirt or dust that could have been on them, and then they were dried until the surface of each one was absolutely dry. The aggregates were examined to guarantee that they were in accordance with the standards established by the Indian government.

Table 2.2: Properties of Coarse aggregates.

Characteristics	Value
Type	Crushed
Maximum size	20 mm
Specific gravity (10 mm) (20 mm)	2.714 2.841
Total water absorption (10 mm) (20 mm)	1.685 % 3.678 %
Moisture content (10 mm) (20 mm)	0.602 % 0.781 %
Fineness modulus (10 mm) (20 mm)	6.51 7.69

1.3 Fine Aggregate

It was determined that the sand that was used in the trial program had been collected from the local area and was suitable for usage in reading zone III. After being passed through a sieve with a mesh size of 4.75 millimetres to eliminate any particles with a size that was larger than 4.75 millimetres, the sand was washed to remove any dust that was still present. It was necessary to do this step in order to guarantee that the sand was absolutely devoid of any contaminants. In order to ensure that the fine aggregates were up to the standards set out by the Indian Standard Specifications IS: 383-1970, they were put through a series of intensive tests.

Table 2.3: Properties of fine aggregates.

Characteristics	Value
Type	Uncrushed (natural)
Specific gravity	2.78
Total water absorption	1.12 %
Moisture content	0.18 %
Net water absorption	0.76 %
Fineness modulus	2.511
zone	III

1.4 Fly ash

Several studies were conducted on the fly ash that was collected from the Thermal Power Plant in Panipat, which is in the state of Telangana. The ASTM C 311 standard requires that both the chemical and physical characteristics of it be investigated and assessed. The experiment's utilization of fly ash, including its chemical make-up as well as its physical properties and features,

Table 2.4: Physical Properties of Fly Ash.

Particulars	Test Results
Fineness Specific Surface (cm2/gm)	3264
Residue on 45 microns(wet sieving)	30.17
Lime Reactivity (kg/cm2)	51.03
Compressive strength(kg/cm2), 28 days	85.99

Dry shrinkage, %	0.04
Soundness expansion by auto clave, %	0.03

Fire exposure to specimens

For the purpose of heating the specimens to very high temperatures, an electric furnace that had been created was used. The maximum temperature that could be reached by the electric furnace while it was operating was one thousand degrees Celsius, and this temperature was ultimately used. Cubes of each concrete mix that was meant to endure the heat and flames of a fire provided the companions for the experiment. Additionally, cubes of the remaining mix and HVFA mix were also included in the experiment. At the same elevated temperatures of 100 degrees Celsius, 200 degrees Celsius, 300 degrees Celsius, 400 degrees Celsius, 500 degrees Celsius, 600 degrees Celsius, 700 degrees Celsius, and 800 degrees Celsius, three specimens of each set of concrete mixes of OPC and HVFA were stored. Temperatures ranging from 100 to 800 degrees Celsius were recorded. There was a wide range of temperatures, from exceedingly low to extremely hot. During the course of one hour, two hours, and three hours, each temperature is kept in a steady state for the specific length of time that corresponds to the duration of the time period. Following this step, the samples were exposed to the open air so that the cool air from the surrounding environment could bring the temperature down. The cubes were then subjected to an ultimate failure load test, which was carried out with the assistance of compression testing equipment of the time.

III RESULTS AND DISCUSSION

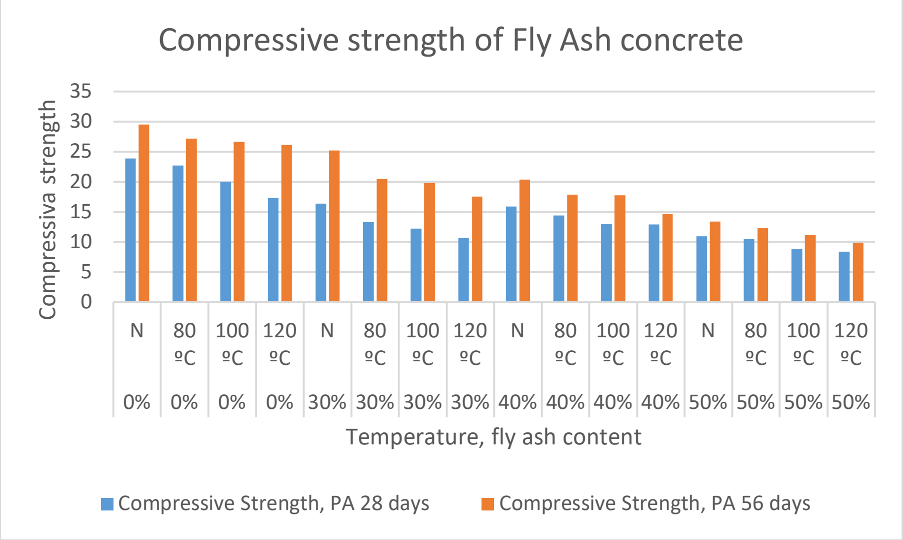
Temperature is one of the most important factors to consider when determining how strong something will be.A rise in temperature leads to a reduction in strength (both in compression and tension), as well as in stiffness (Young's modulus), in a material. [Relationship between cause and effect] The high temperatures caused a chemical reaction in the gel, which resulted in a weakening of the matrix bonding. This, in turn, eventually led to a loss of strength in the fly ash concrete.

1.5 Compressive Strength

In this study, the values of strength characteristics for various fly ash components (0%, 30%, 40%, and 50%) are reported at the end of distinct curing durations (28 days and 56 days). These curing times were chosen since they occurred at different times. These fly ash components were able to include a range of temperatures (40 degrees Celsius, 80 degrees Celsius, 100 degrees Celsius, and 120 degrees Celsius, respectively) by the time these curing durations were over. The temperature at which the material was cured serves as the foundation for these statistics. After the manufacturing process, these values are determined by the temperature at which the material was cured. As a result of the temperature at which the material was cured after it was manufactured, these values are used to calculate the suitable range for the variable. Following the completion of each of the several stages of the healing process, you will be able to see these data. These numbers have been shown after a great number of differing amounts of time have passed, each of which has lasted for a different total amount of time overall. Therefore, in order to ensure that you get the most possible advantage from the experience, we have provided you with a summary of the findings of the research for your consideration. By mixing a number of cement replacements at different curing ages, it is possible to get a wide variety of compressive strengths, as seen by this example. Furthermore, this represents the manner in which the compressive strength of the material shifts in response to variations in the quantity of fly ash that is used and the temperature at which the manufacturing process is carried out. The value of the compressive strength was obtained by first averaging the results of three separate cylinder tests and then averaging those three results by rounding the result up to the closest whole number. This was done in order to determine the value of the compressive strength. As a consequence of this, having the ability to determine the item's true genuine worth became possible. It is extremely clear that the control mixture (M-0) had a better compressive strength than the concrete combinations that included 30%, 40%, and 50% fly ash as replacement levels. This was the case regardless of the age of the concrete components. Additionally, during the course of time, the compressive strength of each and every combination grew. On the other hand, it is clear that the compressive strength of the control combination was lower than the compressive strengths of the fly ash-containing mixtures across all age groups. It did not matter how old the pairings were; this was always the case. On the other hand, when fly ash was used in place of cement in the concrete mixes to varied degrees, the compressive strengths that were produced were lower than those of the combination that included the control mixture (M). On the other hand, as compared to the concrete mixture that included the standard control mixture, the compressive strength of the blends that included 30%, 40%, and 50% fly ash as a substitute for cement was lower. The findings of this investigation were recorded for each of the three fly ash inclusion percentages (M). It was only recently that the American Concrete Institute published a document that detailed the conclusions of the research, and it has only just lately been accessible to the public. It has not been too much longer since the publication of the magazine known as "Journal of the American Concrete Institute." The compressive strength of concrete mixes that included thirty, forty, or fifty percent fly ash as a replacement for cement exhibited a discernible decline as the temperature increased. The findings demonstrated that this pattern was present in each of the three separate percentage levels. The percentage of fly ash that was added to the material resulted in a reduction in the amount of compressive strength that the material had. That was always the case, regardless of the temperature that was experienced outdoors. There is a possibility that the drop in compressive strength of the material is connected to the rise in temperature, which was the direct cause of the phenomenon. This increase in temperature was also the direct source of the event that came about. As a consequence of this, it is reasonable to infer that the material continued to become increasingly fragile throughout the course of time.

Table 3.1: Compressive Strength (MPa)

Fly Ash Content, %	Temperature, ºC	Designation	Compressive Strength, PA	
			28 days	56 days
FA-0%	N	MIX 0	23.89	29.49
FA-0%	80 ºC	MIX 1	22.68	27.19
FA-0%	100 ºC	MIX 2	19.99	26.64
FA-0%	120 ºC	MIX 3	17.35	26.10
FA-30%	N	MIX 4	16.40	25.19
FA-30%	80 ºC	MIX 5	13.25	20.49
FA-30%	100 ºC	MIX 6	12.23	19.768
FA-30%	120 ºC	MIX 7	10.61	17.52
FA-40%	N	MIX 8	15.89	20.39
FA-40%	80 ºC	MIX 9	14.36	17.88
FA-40%	100 ºC	MIX 10	12.99	17.71
FA-40%	120 ºC	MIX 11	12.90	14.62
FA-50%	N	MIX 12	10.90	13.38
FA-50%	80 ºC	MIX13	10.49	12.32
FA-50%	100 ºC	MIX 14	8.89	11.15
FA-50%	120 ºC	MIX 15	8.39	9.88

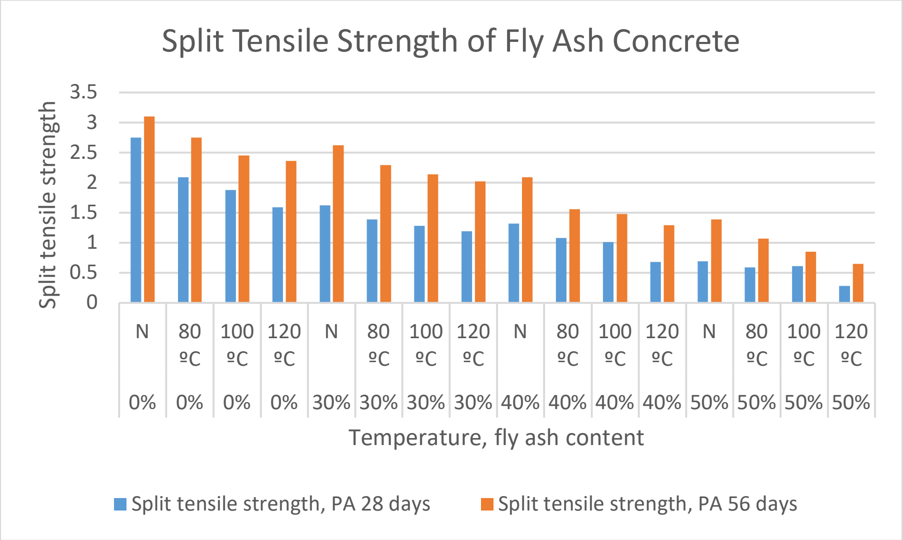


Split tensile strength

It was shown that the split tensile strength of Class F fly-ash traditional concrete at different temperatures (with 30%, 40%, and 50% fly ash and a w/c ratio of 0.5) was entirely reliant on the air temperature as well as the quantity of fly ash that was used in the mixture. This was the case regardless of the temperature. This was the case regardless of the number of percent fly ash that was included in the mixture, which might be anywhere from thirty to fifty percent. This influence was seen, and it was shown that the split tensile strength of Class F fly cementitious materials was impacted by the quantity of fly ash that was used in addition to the temperature at a variety of temperatures. This conclusion was proven feasible by the fact that it really occurred, namely since the quantity of fly ash that was utilised in the mixture increased in direct proportion to the split tensile strength of Class F fly ash concrete. The data that was acquired from the tests that were carried out on the concrete at a variety of temperatures led to the conclusion that was made for this particular experiment. Over the course of that time period, a number of experiments were carried out. It is possible to determine the degree of variation in the strength by examining the values of and for the split tensile strength. In a manner that was analogous to the connection that existed between those two or more components and the influence that it had on compressive strength, the relationship between temperature and fly ash content in the material had an effect on the amount of splitting tensile strength that the material had. At four different temperatures—40, 80, 100, and 120 degrees Celsius—it was shown that there were significant differences in the split tensile strength of replacements manufactured with Class F fly ash. These differences were found to be among the most significant. When compared to the variations that were seen in the compressive strength example, this stood in stark contrast. In instance, it was shown that the changes in split tensile strength were much bigger than the differences in compressive strength variables. Giving an extra reference is something that is really necessary. The fact that this is the case shows that the connection between the fly ash content and the split tensile strength is inverse throughout a wide temperature range. Upon analysing the results of a large number of separate studies, this becomes abundantly clear. Among the pieces of data that supported this assertion was the fact that the split tensile strength reduced as the temperature increased. The following illustration illustrates how strong the association is, regardless of the temperature ranges that are taken into consideration: It was discovered that there is an inverse relationship between the total quantity of precipitation and the rate of temperature increase, with the rate of temperature rise being higher than the rate of precipitation.

Table 3.2: Split tensile strength

Fly Ash Content, %	Temperature, ºC	Designation	Split tensile strength, MPA	
			28 days	56 days
FA-0%	N	MIX 0	2.75	3.10
FA-0%	80 ºC	MIX 1	2.09	2.75
FA-0%	100 ºC	MIX 2	1.88	2.45
FA-0%	120 ºC	MIX 3	1.59	2.36
FA-30%	N	MIX 4	1.62	2.62
FA-30%	80 ºC	MIX 5	1.39	2.29
FA-30%	100 ºC	MIX 6	1.28	2.14
FA-30%	120 ºC	MIX 7	1.19	2.02
FA-40%	N	MIX 8	1.32	2.09
FA-40%	80 ºC	MIX 9	1.08	1.56
FA-40%	100 ºC	MIX 10	1.01	1.48
FA-40%	120 ºC	MIX 11	0.68	1.29
FA-50%	N	MIX 12	0.69	1.39
FA-50%	80 ºC	MIX13	0.59	1.07
FA-50%	100 ºC	MIX 14	0.61	0.85
FA-50%	120 ºC	MIX 15	0.28	0.65

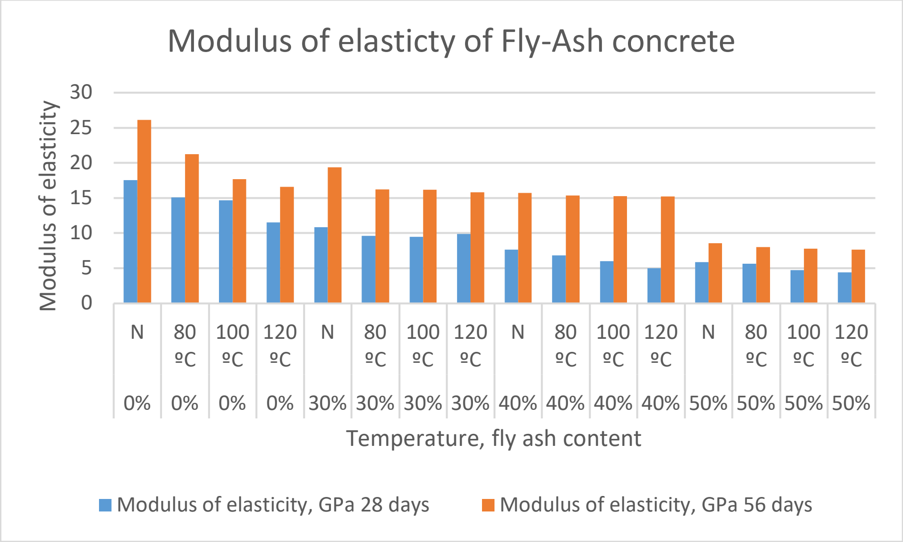


1.6 Modulus of elasticity

Calculating the slope of the chord that stretches from the origin to an arbitrary point on the stress-strain curve is how this inquiry determines the secant modulus, which is also known as the modulus of elasticity. This modulus may be found by looking at the stress-strain curve. This is the method that is used to calculate the modulus of elasticity. This step has to be completed before proceeding with the calculation of the secant modulus. Within the parameters of this particular experiment, the value of the secant modulus was found to correspond to one-third of the maximum stress. In order to acquire an accurate result, the modulus of elasticity of concrete mixes was measured 28 and 56 days after they were mixed. This was done to get the most precise reading possible. Class F fly ash temperatures are 40 degrees Celsius, 80 degrees Celsius, 100 degrees Celsius, and 120 degrees Celsius. When contrasted with the modulus of the control mixture, the findings of the tests suggested that the modulus of concrete could possibly be reduced by using a significant quantity of fly ash as a component of the mixture. This was in comparison to the modulus of the mixture that served as the control. The results of the testing unequivocally demonstrated that this is the case. The rate at which the temperature increased had a negative correlation with the quantity of precipitation that was received.

Table 3.3: Modulus of elasticity

Fly Ash Content, %	Temperature, °C	Designation	Modulus of elasticity, GPa	
			28 days	56 days
FA-0%	N	MIX 0	17.56	26.14
FA-0%	80 ºC	MIX 1	15.09	21.26
FA-0%	100 ºC	MIX 2	14.68	17.71
FA-0%	120 ºC	MIX 3	11.52	16.56
FA-30%	N	MIX 4	10.85	19.35
FA-30%	80 ºC	MIX 5	9.65	16.25
FA-30%	100 ºC	MIX 6	9.45	16.19
FA-30%	120 ºC	MIX 7	9.89	15.79
FA-40%	N	MIX 8	7.68	15.71
FA-40%	80 ºC	MIX 9	6.85	15.36
FA-40%	100 ºC	MIX 10	6.01	15.26
FA-40%	120 ºC	MIX 11	5.02	15.19
FA-50%	N	MIX 12	5.84	8.55
FA-50%	80 ºC	MIX13	5.65	7.99
FA-50%	100 ºC	MIX 14	4.74	7.77
FA-50%	120 ºC	MIX 15	4.39	7.65



Modulus of Elasticity of Fly-Ash Concrete

IV CONCLUSIONS

- A decrease in the compressive strength of the concrete was found to have a direct correlation with the quantity of cement that was substituted with fly ash classified as Class F. On the other hand, regardless of the proportion of cement that was substituted with fly ash, there was a general trend toward an increase in strength with increasing age across the board.
- Because of the many changes in temperature, the compressive strength saw several shifts. The compressive strength of the material decreased from room temperature to 120 degrees Celsius as the temperature increased.
- Also, the modulus of elasticity and the splitting tensile strength increased with age for each level of replacement of cement with fly ash up to 50%, but they both declined with higher volumes of fly ash. This was the case irrespective of the amount of cement that was substituted with fly ash. Despite the fact that the replacement value, which could have been either zero or fifty percent of the entire sum, was unknown, this was nonetheless the case.
- When the temperature was raised up to 120 degrees Celsius, a drop in splitting tensile strength as well as a decrease in the modulus of elasticity were noticed. When high temperatures were put on the fly ash concrete, its strength went down because the chemical changes to the gel made it harder for the matrix to stick together.
- Although there were no shear type failures that took place, the specimens failed in the loading direction after developing several longitudinal (vertical) fractures. However, the common type of failure did not take place.

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